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AN EXPERIMENTAL ANALYSIS OF PROCESS PARAMETER ON CNC PLASMA ARC CUTTING MACHINE

VIPUL M VASAVA & RAJNIKANT C BIDAJWALA

Assistant Professor, Ipcowala Institute of Engineering and Technology, Dharmaj, Anand, Gujarat, India

ABSTRACT

Plasma arc cutting (PAC) is a widely used industrial process for the cutting of different types of metals in several operating conditions. Since last many years, the precise and accurate machining technology of hard metals (ferrous, nonferrous and glass) is gaining so much importance in the modern industry. Now a day, non –conventional machining technology has become the first choice for the engineers and technicians. In this advanced technological process, the CNC plasma arc machining is gaining terrible background in industry. CNC Plasma arc machining is capable of producing more accurate and more finished machining of complicated non-symmetrical. The main objective and targets of this practical experiment are based to achieve the optimal value of MRR & surface Roughness of EN31 materials widely used in Plasma Arc cutting machine. Taguchi method is used for design of experimental approach to optimize the process. Various input parameters like the selection of cutting parameters, gas pressure, current flow rate, cutting speed and Arc gap are taken for the experimental investigation

KEYWORDS: Introduction, CNC Plasma Arc Cutting Machine, DOE, Taguchi Method, ANOVA, Regression Analysis, Minitab

INTRODUCTION

In a non-conventional machining process, the most suitable machining process is Plasma arc cutting (PAC). It is capable of machining of metals like mild steel, stainless steel, titanium alloy and cast iron that can be processed. This technique is employed for non-ferrous metals and alloys i.e. aluminium, copper, tin, magnesium and other alloys. Plasma arc machining or plasma arc cutting is a process that is used to cut precision profiles, patterns, sheets of different types, with the help of a plasma torch or Plasma gun.

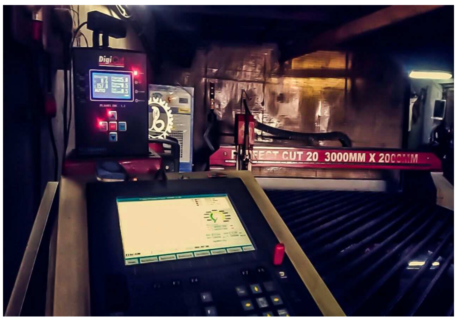

Figure 1: CNC Plasma Arc Cutting Machine

Plasma cutting technology is one, in which argon, nitrogen and compressed air are used to produce a plasma jet, and then they are used to cut nonferrous metal, stainless steel and black metal by the high temperature of the highly compressed plasma arc and the mechanical erosion of the first plasma jet.

OBJECTIVES

It is found already, many works have been done in MRR and Surface finish, but very little work has been done on optimization of Plasma Arc Cutting. Here in this work, we will try to find out optimal value of MRR and SURFACE ROUGHNESS (Ra).

Alloy steel EN31 materials are cheaply available and widely used in Plasma Cutting Machine. Taguchi method, using design of experimental approach can be used to optimize the process. Here, we apply D.O.E approach for modeling of MRR in PAC process, and the various input parameters will be taken under experimental investigation and then model will be prepared, and again experimentation work will be performed. The results obtain will be analyzed and the models will be produced by using MINITAB17 software. This will help in improving the effective and efficient working of the PAC process.

Experimentation

For experimentation, we have taken the various parameters like gas pressure, current flow rate, cutting speed, Arc gap etc. There are some fixed variables in plasma arc cutting process, which is shown in Table 1.

Table 1

Sr No	Fixed Parameter	Fix Value
1	Material type(EN31 steel)	12mm
2	kerf	5mm

Specimen Preparation

15 test specimens, having dimension 60mm x 150mm x 12mm were prepared for the experimental work. The material for test specimen was high carbon alloy steel EN31.

TOTAL WEIGHT OF TEST SPECIMEN=14.42 kg

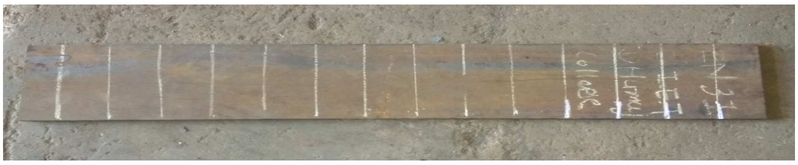

Figure 2: Working Specimen

Various Input parameters like Voltage, Current Flow Rate, Arc Gap, Kerf (width of cut). Cutting Speed, Material Type and Thickness, cutting gas pressure etc have been taken as input parameter in CNC Plasma arc cutting machine (PAC).

Table 2: Orthogonal Array with Standard L16 Array

Sr. No	Cutting Speed	Arc Current	Gas Pressure	Arc Gap
1	160	55	4.8	2
2	160	60	4.9	3
3	160	65	5	4
4	160	70	5.1	5
5	260	55	4.9	4
6	260	60	4.8	5
7	260	65	5.1	2
8	260	70	5	3

Table 2: Contd.,				
Sr. No	Cutting Speed	Arc Current	Gas Pressure	Arc Gap
9	360	55	5	5
10	360	60	5.1	4
11	360	65	4.8	3
12	360	70	4.9	2
13	460	55	5.1	3
14	460	60	5	2
15	460	65	4.9	5
16	460	70	4.8	4

Experimental Layout in Coded Factor Levels

There are four factors and four levels, which are shown in Table 2.

Table 3: Table for Values of Variables at Different Level

Control Factor	Unit	Level 1	Level 2	Level 3	Level 4
Gas pressure	Bar	4.8	4.9	5.0	5.1
Arc current	Ampere	55	60	65	70
Cutting speed	mm/min	160	260	360	460
Arc gap	Mm	2	3	4	5

After deciding parameters and levels as shown above, orthogonal array L16 was decided as per degree of freedom of each factor, and dof of interaction among the parameters. Data of parameters was collected in such a way that, it did not damage or cause any accident to operator and as per literature review. Now, experiment was performed as per orthogonal array (L16) on Plasma Arc Cutting Machine. Out puts like MRR and surface roughness is being given in tabulated form. After the experimental results have been obtained, analysis of the results was carried out analytically as well as graphically. Graphical analysis was done by MINITAB, showing interactions of all parameters. Then, ANOVA of the experimental data was done to calculate the contribution of each factor in each response. Then, we calculated S/N ratio for MRR and surface roughness of specimens.

Then, we obtained optimal conditions calculated for MRR and surface roughness of specimen. The following table shows readings of MRR and surface roughness at each experiment, it also shows S/N ratio for MRR and surface roughness in each experiment.

Table 4: Value of Different Parameter

Sr No	Cutting Speed	Arc Current	Gas Pressure	Arc Gap
1	160	55	4.8	2
2	160	60	4.9	3
3	160	65	5	4
4	160	70	5.1	5
5	260	55	4.9	4
6	260	60	4.8	5
7	260	65	5.1	2
8	260	70	5	3
9	360	55	5	5
10	360	60	5.1	4
11	360	65	4.8	3
12	360	70	4.9	2
13	460	55	5.1	3

Table 4: Contd.,				
Sr No	**Cutting Speed**	**Arc Current**	**Gas Pressure**	**Arc Gap**
14	460	60	5	2
15	460	65	4.9	5
16	460	70	4.8	4

Table 5: Experimental Layout and S/N Ratios for MRR and Surface Roughness

Cutting Speed	Arc Current	Gas Pressure	Arc Gap	MRR	SR	SNR For MRR	SNR For SR
160	55	4.8	2	0.488	3.9	-6.2316	-11.8213
160	60	4.9	3	0.4276	3.7	-7.3792	-11.364
160	65	5	4	0.2385	2.7	-12.4502	-8.6273
160	70	5.1	5	0.5371	3.5	-5.3989	-10.8814
260	55	4.9	4	0.5576	4.3	-5.0735	-12.6694
260	60	4.8	5	0.4917	5.7	-6.166	-15.1175
260	65	5.1	2	0.5288	6.8	-5.5342	-16.6502
260	70	5	3	0.4321	5.8	-7.2883	-15.2686
360	55	5	5	0.4724	7.1	-6.5138	-17.0252
360	60	5.1	4	0.367	4.4	-8.7067	-12.8691
360	65	4.8	3	0.4903	6.5	-6.1908	-16.2583
360	70	4.9	2	0.3907	3.8	-8.1631	-11.5957
460	55	5.1	3	0.3973	6.1	-8.0176	-15.7066
460	60	5	2	0.4275	4.3	-7.3813	-12.6694
460	65	4.9	5	0.4481	2.5	-6.9725	-7.9588
460	70	4.8	4	0.6413	3.5	-3.8588	-10.8814

Table 6: Anova Analysis

Number	Cutting Speed	Arc Current	Arc Pressure	Arc Gap	MRR	SR
1	160	55	4.8	2	0.488	3.9
2	160	60	4.9	3	0.4276	3.7
3	160	65	5.0	4	0.2385	2.7
4	160	70	5.1	5	0.5371	3.5
5	260	55	4.9	4	0.5576	4.3
6	260	60	4.8	5	0.4917	5.7
7	260	65	5.1	2	0.5288	6.8
8	260	70	5.0	3	0.4321	5.8
9	360	55	5.1	5	0.4724	7.1
10	360	60	4.8	4	0.3670	4.4
11	360	65	4.9	3	0.4903	6.5
12	360	70	5.1	2	0.3907	3.8
13	460	55	5.0	3	0.3973	6.1
14	460	60	4.9	2	0.4275	4.3
15	460	65	4.8	5	0.4881	2.5
16	460	70	5.1	3	0.6956	3.9

Analysis of Variance for Surface Roughness Total no of runs (n) = 30 Total degree of freedom ft = n - 1 = 16-1=15

Four factors and their levels:

Cutting Speed A: A1, A2, A3, A4

Arc Current B: B1, B2, B3, B4

Air Pressure C: C1, C2, C3, C4

Arc Gap: D1, D2, D3, D4.

Degree of freedom:

Factor A – Number of level of factor A - 1 = FA = 3

Factor B – Number of level of factor B - 1 = FB = 3

Factor C – Number of level of factor C - 1 =FC = 3

Factor D – Number of level of factor D - 1 =FD=3

For error FE = FT – FA – FB – FC-FD = 15 – 3 – 3 – 3-3 = FE = 3

T = Total of all depth value results = 7.336 Correction factor C.F. = (T2 / n) = (20.6352 / 30) = 3.58

Total sum of squares:

ST = ∑ - C.F. = 15.8292 – 14.1934 = 1.6358

Table 7: Anova Scaning Table for MRR

Source of Variation	Sum of Squares	Variance (Mean Square)	Variance Ratio F	Percentage Contribution
Factor-A, Cutting Speed	0.22	0.773	0.1	34.92%
Factor-B, Arc Current	0.24	0.08	0.1	38.09%
Factor-C, Gas Pressure	0.21	0.7	0.69	33.02%
Error – E	0.16	0.0573	0.073	5.96%
Total	**0.82**			

Table 8: Summary of Anova Calculation

Source of Variation	Sum of Squares	Variance	Variance Ratio	Percentage Contribution
Factor A Cutting Speed	9.66	3.22	2.77	14.32%
Factor B Arc Current	20.17	6.72	5.97	30.85%
Factor C Air Pressure	16.69	5.59	4.79	25.52%
Factor D Arc Gap	16.54	5.51	4.75	25.29%

Regression analysis can be done in two ways 1.Bivariate regression and 2.Multiple regression

The regression equation for MRR is

MRR = 1.67 + 0.000095 Cutting Speed + 0.00125 Arc Current - 0.274 Gas Pressure + 0.0100 Arc Gap

S = 0.0980518 R-Sq = 68.56% R-Sq (adj) = 57.8%

Table 9

Predictor	Coef	SE Coef	T	P
Constant	1.673	1.24	1.49	0.165
Cutting Speed	0.0000948	0.0002193	0.43	0.674
Arc Current	0.001248	0.004385	0.28	0.781
Gas Pressure	-0.2742	0.2193	-1.25	0.237
Arc Gap	0.010000	0.2193	0.46	0.657

Table 10: Analysis of Variance

Source	DF	SS	MF	F	P
Regression	4	0.19613	0.004903	0.51	0.730
Residual Error	11	0.105756	0.009614		
Total	**15**	**0.125639**			

Model Adequacy Check: The P- value of Regression equation (0.730) indicates that the regression model is significant. The coefficient of determination (R2), which indicates the goodness of fit for the model, so the value of R2 =68.56% which indicates the high significance of the model.

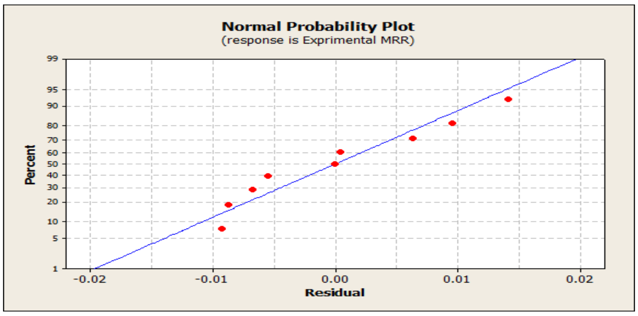

Figure 3: Normal Probability Plot for Residuals of MRR

This graph indicates that the residual follows a straight line, and there are no unusual patterns or outliers. As a result, the assumptions regarding the residual were not violated and the residuals are normally distributed.

FIRST ORDER LINEAR MODEL FOR SURFACE ROUGHNESS

The regression equation for SR (Ra) is

SR = - 2.3 + 0.00175 Cutting Speed - 0.0700 Arc Current + 2.30 Gas Pressure - 0.180 Arc Gap

Table 11

Predictor	Coef	SE Coef	T	P
Constant	-2.26	18.09	-0.12	0.903
Cutting Speed	0.001750	0.003537	0.50	0.630
Arc Current	-0.0700	0.07054	-0.99	0.342
Gas Pressure	2.300	3.527	0.65	0.528
Arc Gap	-0.1800	0.3527.	-0.51	0.620

S = 1.57737 R-Sq = 71.89% R-Sq (adj) = 63.01%

Table 12: Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	4.768	1.192	0.48	0.751
Residual Error	11	27.369	2.488		
Total	**15**	**32.137**			

Model Adequacy Check: The P- value of Regression equation (0.751) indicates that the regression model is significant. The coefficient of determination (R2) indicates the goodness of fit for the model, so the value of R2 =71.89% indicates the high significance of the model.

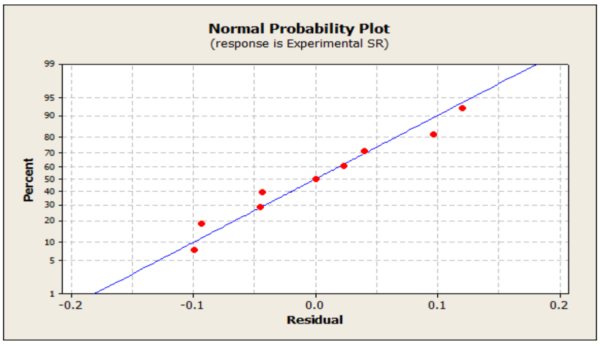

Figure 4: Normal Probability Plot for Residuals of Surface Roughness

This graph indicates that the residual follows a straight line, and there are no unusual patterns or outliers. As a result, the assumptions regarding the residual were not violated and the residuals are normally distributed.

RESULTS

The Optimum levels of parameters for maximizing MRR are: **Gas Pressure:** 4.9 Bar, **Current:** 55 A,

Cutting Speed: 260 mm/min, **Arc Gap:** 4mm

The optimum levels of parameters for minimizing Surface Roughness (Ra) are. **Gas Pressure:** 4.8 Bar

Arc Current: 65 A, **Cutting Speed:** 460 mm/min, **Arc Gap:** 5 mm

CONCLUSIONS

In the presented work, experiments were carried out with response variables that are surface roughness and material removal rate, with process parameters as cutting speed, arc current and gas pressure. There are 16 experimental readings taken for all variables to conduct the parametric study. The ANOVA test gives the result for material removal rate and surface roughness. In the MRR case, arc current (38.09%) and cutting speed (34.92%) are the most effective parameter. In the case of surface roughness, arc current (30.85%) and air pressure (25.52%) are the most effective parameter. As per regression analysis, the mathematical models of first order for MRR and SR (Ra) are showing significant results. The mathematical equation for MRR of first order is of R-sq of 68.56% and for Surface Roughness (Ra), it is R-sq 71.89%, which is acceptable.

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